

Precision Ag: How to get and what to do with coloured maps

Since our first editorial, the Precision Ag Corner is following the cycle of Precision Agriculture (PA) described in the first issue. Until now, we have described how to obtain georeferenced data using visual observations or Global Navigation Satellite Systems together with soil or crop sensors. That is the purpose of the first stage of the PA cycle. We need to bear in mind that the final objective of PA is making more informed management decisions. For this purpose it is crucial to turn the collected data during stage 1 into useful information (stage 2) and, subsequently, into clever management decisions (stage 3). In this issue, we describe how to convert data into information in the form of digital maps. In 2018, New Ag International has again partnered with the Research Group on AgrolCT & Precision Agriculture (GRAP) of the University of Lleida-Agrotecnio Center in Catalonia, Spain. In every issue of the magazine *Jaume Arnó*, José A. Martínez-Casasnovas and Alexandre Escolà, with our Editorial Team, will put together an editorial whose ambition is to help the various stakeholders bridge the gap between datanomics and commercial farming.

MAP-BASED PRECISION AGRICULTURE takes advantage of Global Navigation Satellite Systems and visual observations or sensing techniques to create digital maps of the fields. Each map is a layer providing information on the spatial distribution of a single agronomic variable. Real-time sensor-based PA neither requires nor has time to create and use such maps. In map-based PA, the way the maps are created and how to interpret them is essential to make correct management decisions.

MAPPING THE PLOTS FOR A BETTER CROP MANAGEMENT

In previous articles, some of the most used proximal and remote sensors were referenced. With the help of suitable systems for georeferencing the acquired data, these sensors finally allow different soil and crop characteristics to be measured at different spatial resolutions. Yield, plant vigour expressed according to vegetation indices, such as the NDVI (Normalised Difference Vegetation Index), or the soil apparent electrical conductivity (ECa), are known examples of data made available to farmers and managers. Obviously, the cycle of the PA is not interrupted at this first stage and, once all this spatial data have been obtained, it is time to map and interpret the data. To be applied in map-based PA, maps must meet some requirements. Thus, a map will not be very useful if it is merely a coloured dot map representing measurements acquired in the plot. Farmers need to take advantage of the mapped

information and, for this purpose, maps should refer to the information on the same location grid within the plot. In GIS (Geographic Information Systems) terminology it is called a map in raster format or a surface map, which manages to represent the information continuously, covering the total area of the plot. Although moving from discrete data to surface maps will require applying a spatial interpolation process (not always available in commercial software), this is the first step for farmers and advisors to use the mapped information to make better agronomic decisions. In a second stage, the delimitation of different agronomic zones with similar crop behaviour or performance is considered for site-specific crop management (SSCM). The zone delimitation will be based on comparing and overlapping surface maps using appropriate classification procedures. How to move from data to surface maps and how to convert these maps into zone maps is the main issue addressed in this PA Corner. As an example, Figure 1 shows this process for a maize plot. A yield surface map is obtained from the combine harvester yield monitor. This is then used to obtain a map of potential management zones (PMZ) by classifying the areas of highest and lowest yield within the plot.

FROM DATA TO USABLE AGRONOMICAL MAPS: A PROCESS WITH SEVERAL STEPS

As suggested in the report entitled 'Precision Agriculture: an opportunity for EU farmers', requested

in 2014 by the European Parliament's Committee on Agriculture and Rural Development, 'there is a need of knowledge and skill on how to transform, through Geographic Information Systems (GIS), data collected by different sensors and geo-referenced into maps to provide information on crop physiological status and soil condition status'. The need for surface maps (maps with raster coverage) has already been mentioned. Imagine you want to compare a series of three yield maps obtained in successive campaigns. Only when the yield in each map is referred to the same reference grid, it is then possible to compare and quantify how the yield has varied in each location and/or area within the plot in a reliable way. Therefore, by arranging the data conveniently, it becomes easier to extract a deeper knowledge of our yield data afterwards, being possible to analyse, for example, whether the crop yield follows a specific pattern of spatial variation that remains stable over time. The analysis of the spatio-temporal variation of the crop yield is a fundamental aspect to take into account when deciding whether or not to perform a differentiated management in a particular plot or SSCM. Following the example of yield maps, there is another aspect that often goes unnoticed and that, having questioned the usefulness of interpolated surface maps, it may end up convincing the most sceptical farmers. Everyone agrees that calibration of yield monitors is very important to achieve sufficient

accuracy in yield measurements to make site-specific management decisions. To determine yield in arable crops, for instance, three parameters need to be registered every time the monitor acquires data (for example, every 1.5 seconds): grain mass, harvested area and location coordinates. Let's take the example of a combine harvester of 7.5 m cutting width moving at 6.5 km/h. When the yield monitor measurement is 3.5 tons/ha at one point, this means that the yield sensor has detected a grain mass of 7 kg harvested in an area with dimensions 7.5 m (width) by 2.7 m (distance travelled in 1.5 s). However, it is necessary an elapsed time given the existing flow delay since the grain is harvested until it passes in front of the sensor to be quantified. During this time-lag (between 10-15 s that the operator must validate) the combine keeps advancing and harvesting. So, due to the more than likely mix of grains during the flow through the harvester, who can ensure the accuracy of the corresponding point-to-point yield measured data? Wouldn't it be more convenient to map the acquired data by means of a method that, taking into account the data collection intervals, achieves smoothing of the acquired data by providing a more realistic map? That is why spatial interpolation using geostatistical methods is the best option. However, before interpolation data must be checked to remove outliers and pre-processed to correct errors that may occur during data acquisition.

INTERPOLATION OF DATA: THE ROLE OF GEOSTATISTICS

Apart from yield monitors and other proximal sensors that provide data at high spatial resolution (i. e. on-the-go soil sensors for ECa measurements), many times farmers only have sparse data obtained by sampling for some soil and crop properties that, on the other hand, are essential for agricultural management decision making. We

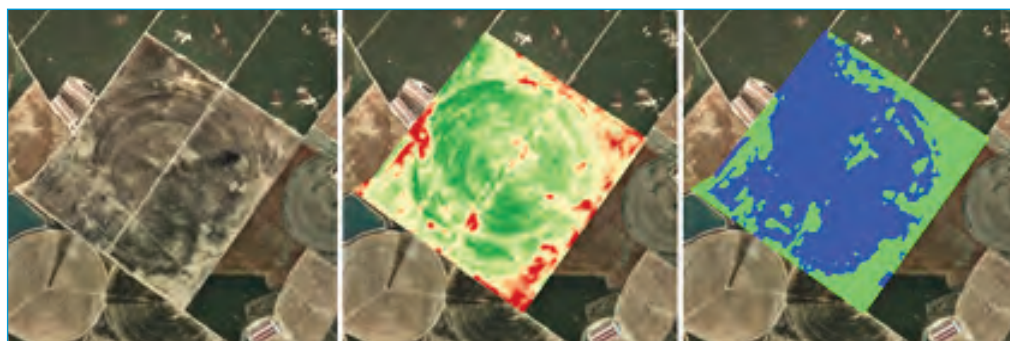


Figure 1: Maize plot harvested with yield monitor (left) and the corresponding yield surface map obtained by interpolation (centre). Map of yield zones (low-green and high-blue) for the differentiated management of the plot (right).

refer to properties related to fertility and soil moisture or some crop parameters. In short, farmers can receive a lot of data but with different spatial support requiring, in all cases, detailed maps for a correct interpretation. Maps are not only a fancy way to present field data. Since they are the base information to support the decision making process in map-based PA, they should be as accurate as possible. Geostatistics is the science that allows the required maps to be created as it has been recognized by experts in this area. Agreeing that geostatistical interpolation is the solution, let's see what steps are necessary and the software available. In the field of Precision Agriculture, ordinary kriging is the usual adopted interpolation procedure for the generation

of maps. Two different actions are involved in the following order. First and foremost, it is necessary to analyse how the observed data vary spatially using the variogram function (or variographic analysis). Taking again the example of yield maps, the variogram makes it possible to quantify which is the expected yield variation between two different locations within the plot. This information is essential for the next interpolation phase (kriging). Specifically, yield grid values are obtained by appropriately weighting the monitored real yield values according to their relative location. Although some generic GIS software provides interactive tools for geostatistical and spatial data analysis, specific programmes are also available to obtain maps through a geostatistical interpola-

tion process. This is the case of the VESPER programme developed by the Precision Agriculture Laboratory (PA Lab) of the University of Sydney. VESPER is distributed as a shareware programme and can be downloaded from the PA Lab website. In addition to being able to fit different variogram models, the programme is the only one that offers the possibility of interpolation based on the use of local variograms. This is a feature much appreciated in Precision Agriculture because it manages to obtain maps of greater reliability when large amounts of data are available within the same plot. Instead of trying to fit a global variogram for the whole plot, the programme allows a particular variogram (or local variogram) to be

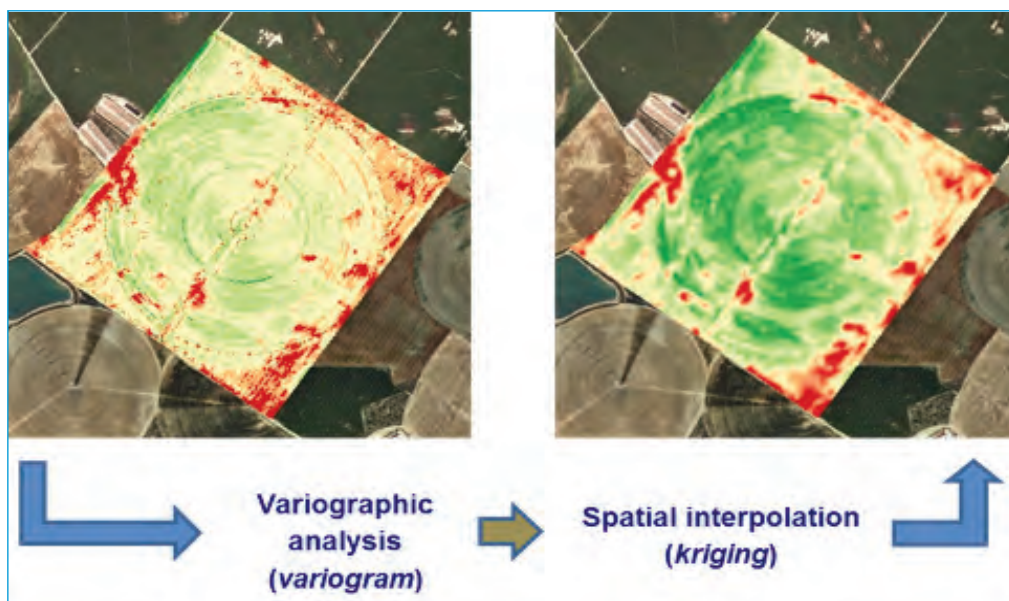


Figure 2: Dot map of the yield points acquired on a maize plot (left), and surface map of the same plot obtained by kriging on a 5m grid (right).

Interview with Dr. Rob Bramley, CSIRO, South Australia



Dr Rob Bramley is a Senior Principal Research Scientist with CSIRO, based at the Waite Campus, in Adelaide, South Australia. Originally a Soil Scientist by training, he has over 20 years experience in Precision Agriculture research.

You have been working in Precision Agriculture for several years. Which is the most critical stage when trying to apply map-based solutions: sampling/sensing variables, creating the map, interpreting consistently across a variety of contexts and situations, delineating management zones or prescribing profitable decisions from them?

There is an old cliché that says 'you cannot manage what you cannot measure' so clearly measuring things properly is important. This means that the tools being used for measurement (yield monitors, sensors, lab equipment, etc) need to be properly calibrated. But there is also a trap to fall into in chasing too much analytical precision. In my experience, farmers who adopt PA are really only inter-

ested in a 'low', 'medium' and 'high' classification, sometimes just 'low' and 'high', and for this reason, I tend to think that being able to properly characterize spatial variation is the most critical aspect of developing map based aids to decision making. Of course, the numbers you use for mapping need to be robust, but I think it is pretty critical that you take your samples from the right place, take enough of them, and then process them correctly. I believe that it is well established in the literature that kriging is the optimal map interpolation methodology and I rather despair that many people still use IDW (usually with W just assumed to equal 2) to generate maps – if indeed they even bother to interpolate a continuous map at all! Farmers are running businesses and to make good business decisions, they need good quality data that has been analysed properly and that is what should drive our approach to data processing and analysis.

Many plug&play or blackbox software solutions have appeared in the market to help advisors and farmers "draw" their maps and create their prescriptions. Do you think they are reliable enough? Is there a real need for education in these new topics?

I have only ever seen one piece of commercially available PA software which, in my view, created yield maps properly – and to my knowledge, this is no longer available. I think it is a real problem that in the interests of producing something that 'looks good' quickly, the developers of many mapping programs have ignored the need for maps to be produced using robust methods. Unfortunately, mapping methods like kriging

are computationally slow. They also cannot be used for mapping in 'real-time' because, in the case of yield mapping for example, you need the data for areas that you haven't harvested yet to produce a robust map. An additional problem is that we need to recognize that the knowledge of the farmer is invaluable in the map interpretation process; and this is knowledge that should not be discarded; he/she will probably know their soils well, for example. It certainly makes developing software for PA difficult, but I think this is an area where the commercial providers need to expend considerable effort to improve what is currently available.

"There is an old cliché that says 'you cannot manage what you cannot measure' so clearly measuring things properly is important. This means that the tools being used for measurement (yield monitors, sensors, lab equipment, etc) need to be properly calibrated"

Many farmers are provided with fancy coloured maps of their fields, such as yield maps or vegetation indices, but never use them in their decision making process. What is the matter? Can you suggest a solution?

In Australia, several surveys have been undertaken in the grains industry which show a strong relationship between farmer adoption of PA (yield mapping and use of variable rate fertilizer application in particular) and whether or not the farmer uses a paid agronomic consultant. When an agronomic consultant is employed, the likelihood of adopting a range of sources of information is much greater than when one is not used. Recently, I conducted a survey of over 200 grain farmers and it also showed clearly that a farmer who has yield maps is much more likely to adopt other elements of PA than one who does not have yield maps. So making it much easier to generate yield maps is important for disposing the farmer to adopt other technologies such as crop sensing. Other surveys I have conducted in both the wine and sugar industries suggest strong interest in PA, but that it is being held back by a lack of technical support – people to produce the maps properly, discuss the agronomic implications and assist in the development of zones. And of course, these maps need to be provided in the context of a decision to be made – How much fertilizer to apply? What seed rate to use?

In your opinion, how is PA evolving: are map-based solutions going to prevail? Are real-time sensor-based applications going to take the lead? What would be best, technically, agronomically and economically speaking? Much of the commercially available PA technology presents as 'solutions looking for problems'. Most of the current excitement arounds drones is a good exam-

ple of this, since for the most part, they are not sensing something we cannot already sense from another platform – and if you have a 40m boom spray, you don't need 2cm resolution imagery to inform how to use it. I think this needs to be turned around with the focus placed on the problems that farmers need to solve. So a basic change in commercial philosophy would probably be useful. I think we also need to recognize that agriculture is a multivariate problem; Along with a number of colleagues in Australia, I am involved in a new project in the grains industry which seeks to automate both the acquisition and processing of information that can be brought to bear on the nitrogen (N) fertilizer decision making process and then the implementation of the management decision. Note that we are not seeking to automate the decision making process itself, because that is something that the farmer wants to do him or herself, possibly considering a range of possibilities in making this decision. In other words, we do not want to produce a recipe but may produce a range of possible recipes for the farmer to consider. A preliminary part of this work has seen an extensive effort put into reviewing the whole process of N fertilizer decision making. Our conclusion is that sensor based approaches to N fertilizer management need to take a multi-variate approach. So simply using an NDVI-based crop sensor to spit out a fertilizer recommendation, is not going to 'cut it'; we need to also consider available soil moisture, the condition of the season – how much it has rained so far, and whether there is much likelihood of further rain – the forecast grain price, the fertilizer price and so on.

used for each point of the prediction grid to improve the precision of the interpolation. Certainly, the user must have certain computer skills and, above all, be able to devote time to build the maps. Unfortunately, farmers do not usually meet one or both of these requirements, and the figure of the expert consultant becomes fundamental in this case. Nevertheless, maps created with other procedures might not be accurate enough and might condition the decision making process.

FROM MAPS TO POTENTIAL MANAGEMENT ZONES: AN ADDED DIFFICULTY

Site-specific crop management consists in adjusting the input distribution (such as fertilizers, pesticides, irrigation water, etc.) or even the intensity of agricultural operations to the local requirements. These adjustments may be modulated on the basis of a point-to-point variability or by grouping similar response areas in management zones. In this respect, Management Zones can be defined as sub-regions of a field that express relatively homogeneous combinations of yield-limiting or yield-potential factors, and for which a field-based uniform treatment may not be the most appropriate. Then, the delineation of management zones implies the classification of the spatial variability within the field in different classes. But the key question is: how to do that?

First of all, the delineation of potential management zones should consider all the factors the farmer can afford to map. In particular, and in order to maximize the returns, these should be the most directly related to crop yield or to crop quality. Examples include soil properties such as texture, depth, water retention capacity, nutrient availability, organic matter content and limiting factors such as salt content, drainage problems, etc. In this respect, and since soil properties

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CURRICULUM

Participants will arrive on Sunday evening and transfer to the hotel that will serve as meeting point. The programme will start on Monday morning and finish on Wednesday midday the week following.



are difficult and costly to map, subrogate data such as the apparent electrical conductivity (ECa) that can be measure by on-the-go sensors are frequently used. Other factors to be considered may be the crop development, through the mapping of vigour indices, or even crop yield. Nevertheless, crop vigour varies along the crop cycle and yield may not be stable enough across seasons. Then, to accurately define management zones, supplementary information may be needed, such as soil variability.

After raster continuous maps have been created, which methods do we have to delineate management zones? One of the easiest methods is the reclassification of the spatial data, for example vigour indices, or yield data. Previously, we will have to decide how many classes to create (e.g. 2 classes vigour or yield -low/high- or 3 classes - low/medium/high). According to our experience and

also based on other scientific works, 2 or 3 classes are the optimum. For example, in the case of delineation of zones for wine grape selective harvesting, 2 zones of low/high vigour index or

yield are preferred to 3, since the medium class is usually ambiguous. In other cases, more than 3 zones may complicate the variable-rate application or significant differences in the final yield may

not be found in some of the intermediate classes. Another request for reclassification is the need to establish the boundaries between classes in the continuous variable that we use for zone delimitation

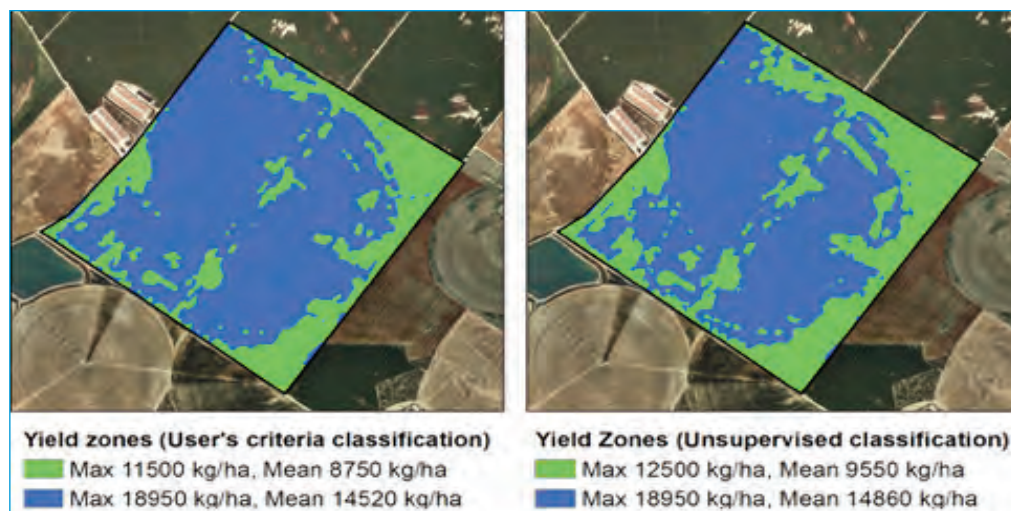


Figure 3: Example of the creation of potential management zones throughout the application of expert knowledge classification (left) and unsupervised classification (ISODATA algorithm) (right). Both maps are based on yield data. In the left map (expert knowledge classification) the user has established the threshold between the low and high yield classes in 11500 kg/ha, while in the unsupervised classification (right map) the computer has determined the threshold in 12500 kg/ha, which results in 2 classes with statistically significant differences.

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(e.g. the vigour index value that separates the low class from the high class). For that, expert knowledge based on previous experience in the relations between the classified variable and the final yield is needed (Figure 3). Nevertheless, this procedure may not assure that the created classes are statistically different, and usually it is based on the reclassification of one related factor (e.g. vigour index), although above we have pointed out that potential management zones could respond to more than one factor.

Unsupervised classification of the spatial factors is the alternative method that can face the limitations of the user's reclassification procedure. In unsupervised classification, image processing software classifies the spatial data (one or more variables at a time) on natural groups of the values of the grid cells in each considered variable, without the user specifying

how to classify these data. This procedure is similar to cluster analysis, where observations (in this case, grid cells) are assigned to the same class because they have similar values. The user must specify basic information such as the variables to use (e.g. vigour index, ECa maps, previous yield maps, etc.) and how many classes he/she wants to create. To do that, the image processing soft-

ware uses a clustering algorithm. The two most frequently used algorithms are k-means and ISODATA (Figure 4). The ISODATA algorithm is similar to the k-means algorithm with the distinct difference that the ISODATA algorithm allows for different number of clusters while the k-means assumes that the number of clusters is known a priori.

In Figures 3 and 4 we show exam-

ples of the creation of potential management zones according to classification of one or more field factors on the basis of expert knowledge or unsupervised (Figure 3, using yield; Figure 4, using combined ECa and NDVI). The different methods can produce different results and it will be the farmers/technicians who make the final decision about which potential zones are finally delin-

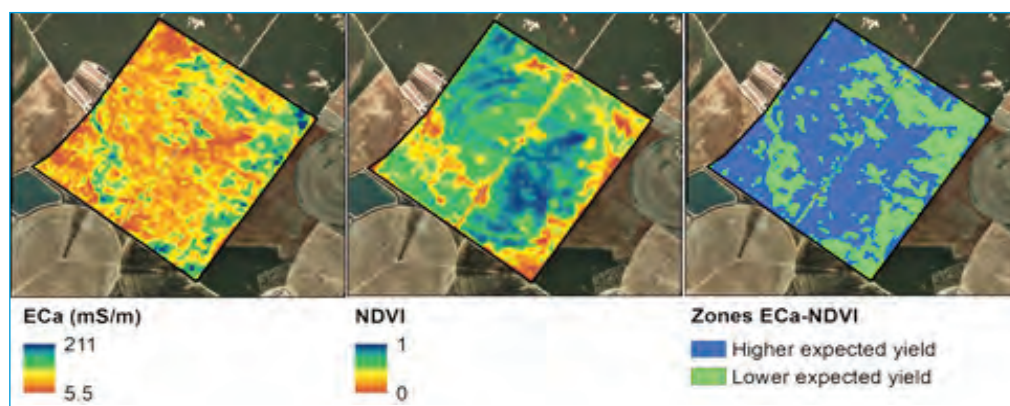


Figure 4: Example of creation of potential management zones based on an unsupervised classification of Apparent Electrical Conductivity (ECa, left) and NDVI (centre). The result (right) shows 2 potential management zones of high and low expected yield.

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Interview with Charlotte Gabriel-Robez - Agriculture Marketing Manager, Airbus Industries, France



Airbus, global leader in aeronautics and space, is also the oldest commercial satellite imagery provider, pioneering the use of remote sensing for a wide range of applications since more than 30 years.

"Monitoring from space is particularly relevant to farming due to the global scale of agriculture, and the pace of vegetation growth. Yet in the early days of remote sensing, satellites were not numerous. There was a need to source imagery from any available satellite to secure a picture of the field at the right point of time during the crop cycle. However, mixing different imagery is challenging: the same vegetation returns different spectral responses as satellites have different sensors. Over the years, Airbus developed expertise in collecting the required imagery on time, and in extracting consistent vegetation indicators, which are robust regardless of the satellite imagery used. These turn-key analytics powered by biophysical inversion enable to quantify biomass or nutrient content, and monitor

fields with no bias, free of ground measurement. Combined with agro-meteorological models, they can be accurately turned into prescriptions to dose fertilizers, water, growth regulators and pesticides, finally helping to minimize the environmental impact of farming. These dependable crop metrics have been used for years in all Airbus agricultural services.

The rapidly growing population, limited farming lands and resources, general movements towards greener practices or commodity price impact on farmers revenues are calling for increased production and more sustainable agriculture. As progress is made in imaging capabilities, space-, air- and infield data gathering, computing, and dissemination, we now have the right tools to achieve this. Hence, precision agriculture platforms are expanding, either initiated by international leaders or start-ups. Yet, to be meaningful and valuable to the farmer, agronomic recommendations require to be finely adapted to the very local context – taking into account the variety, the soil, the weather, and the farming practices. This adaptation demands a close contact to the farmers or crop consultants and a deep local knowledge.

Airbus now aims at offering ag service providers, advisors and agronomists a living reference layer for premium crop analytics. Based on more than 20 years of research and development and served as an API to ease interface with web platforms and integration with other data sources, our ambition with the upcoming Airbus FieldMaps solution is to unlock the potential of satellite and UAV imagery for agriculture".

eated for the target management operation to implement (e.g. fertilization before sowing or side-dressing N application). In both examples, the potential zones could be refined manually to delineate the final zone map.

DECISION MAKING: THE KEY OR THE BOTTLENECK?

Once rational zones with similar properties are created in a field, it is time to properly turn them into useful information. The first approach is using the zones in the map for targeted sampling, that is designing a strategy to take samples only where properties are to be different. Another approach is turning the mapped zones into actual management zones. Thus, each zone has to be assigned a management action: a specific dose rate of a resource to be distributed (e.g. fertilizer, irrigation, plant protection product, seeding, etc.) or a specific intensity of an agricultural operation (e.g. prun-

ing, tillage, etc.) or a specific action to be conducted (e.g. selective harvesting, etc.). That is the bottleneck of Precision Agriculture. What is the right dose rate to be assigned to each zone? What to do in each management zone? The answer of this question is not simple or direct. It certainly depends on each situation. There is no universal answer to the question. It is the task of the farmer or his/her advisor to establish what is the most appropriate action to implement in each zone. It is an agronomical matter and it is not possible to make decisions considering only technological issues.

When management zones are given a specific dose rate or an action to be performed what we have is a prescription map. Prescription maps can be carried out manually or using variable rate technologies on board of agricultural machinery. In the second case, the time-lag to change from one dose rate to the new one and the

working width are additional parameters to be considered in the delineation of management zones. Decision making considerations to

create prescription maps and variable rate technologies will be addressed in the coming two issues, respectively. Stay tuned! ■

Glossary of terms

Kriging is a method of spatial interpolation that allows creating a surface map (or raster map) using a variogram model from real data sampled or supplied by a sensor.

Experimental variogram is a graphic representation of how a property varies within a plot or area according to the distance between different spatial locations. Subsequent variographic analysis allows a **variogram model** to be fitted to describe such variation as the separation distance between sampling points increases.

Site-specific crop management (SSCM) is the 4th stage in the Precision Agriculture cycle, after acquiring data (1 stage), turning it into information (2nd stage) and turning it into management decisions (3rd stage). It consists in managing the crop and performing agricultural operations at a spatial scale smaller than the field, according to prescribed **Management zones**. That means adjusting the inputs (fertilizers, pesticides, irrigation water, manual operations, etc.) to the local requirements. In some countries, SSCM is used as a synonym of Precision Agriculture.

Unsupervised classification is a machine learning procedure to describe hidden structure from "unlabelled" data. It can be applied to classify spatial variables. In this case, the user specifies the spatial variables on the basis of which the classification will be made and the number of classes to create. For that, the computer uses a clustering algorithm that determines the natural, statistical grouping of the data.

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